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On the Finds of Green Toads (*Bufo viridis* Complex) in the Late Cenozoic of the East-European Platform

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Abstract—Bone remains of amphibians from the group of green toads from different Late Pliocene to Holocene localities of the East-European Platform are described. The possibility of finding *Bufo raddei* remains in Western Europe is discussed.

INTRODUCTION

At present Europe is inhabited by two amphibian species of the green toad group: *Bufo viridis* (a true green toad) and *Bufo calamita* (running toad). These two toad species are noted in many publications devoted to fossil herpetofaunas of the Late Cenozoic from Western and Central Europe, as well as western Ukraine (Bolkay, 1913; Dely, 1955, 1957; Brunner, 1956; Kretzoi, 1956; Tatarinov *et al,* 1962, 1969; Janossy, 1963; Vergnaud-Grazzini, 1970; Peters *et al,* 1972; Rage, 1972; Tatarinov, 1973, 1981; Mlynarski, 1977; Sanchiz, 1977, 1979, 1990; Sanchiz *et al,* 1977; Mlynarski *et al.,* 1978; Hodrova, 1981; Kotsakis, 1981; Paunovic, 1984; Bailon, 1986; Holman, 1993). The time of the first appearance is estimated as the Middle Miocene for *B. viridis* and the Late Miocene for *B. calamita* (Sanchiz, 1977).

Fossil material in the southern half of the East-European Platform, referred to as Late Pliocene to Holocene age, contained the remains of green toads. I identified the material to the species level in 23 localities of (1) the Upper Pliocene: Kotlovina, Liventsovka, and Peshchera Zapadnaya in Odessa Catacombs; (2) the Eopleistocene: Karai-Dubina and Kryzhanovka; (3) the Lower Pleistocene: Vol'nayaVershina-II, Kuznetsovka, Trostnyanka, Soglasie-Korostelevo, Troitskoe, Repnoe, and Kholki; (4) the Middle Pleistocene: Gun'ki-II, Gun'ki-III, Posevkino, Chigirin, and Nyaravai; (5) the Upper Pleistocene and Holocene: Brod, Voroncha, Gadyach, Zmeevka-II, Peski-I, and Chernyanka (Fig. 1). Information on the above material was reported in part in regular publications (Ratnikov, 1988, 1989, 1992, 1994a; Kalinovskii and Ratnikov, 1990), and the most complete report on the localities is in the deposition (Ratnikov, 1994b). Besides, the discovery of *B. viridis* and *B. calamita,* one more species, *B. raddei* (Mongolian toad) was found. Today it inhabits Transbaikalia, Mongolia, and Primorskii Krai. All previously reported finds of the Mongolian toad occured in Asia (Bien, 1934; Pei Wen-chung, 1940; Hodrova, 1986; Bakradze and Chkhikvadze, 1988; Borkin, 1988); and only one of them, in the Upper Miocene of present day Kazakhstan (Bakradze and Chkhikvadze, 1988). Inasmuch as this species has been identified in Eastern Europe for 15 localities of different age, osteological substantiation, as well as temporal and spatial distribution of green toads, in particular *B. raddei,* attracts considerable interest. The present paper is devoted to these questions.

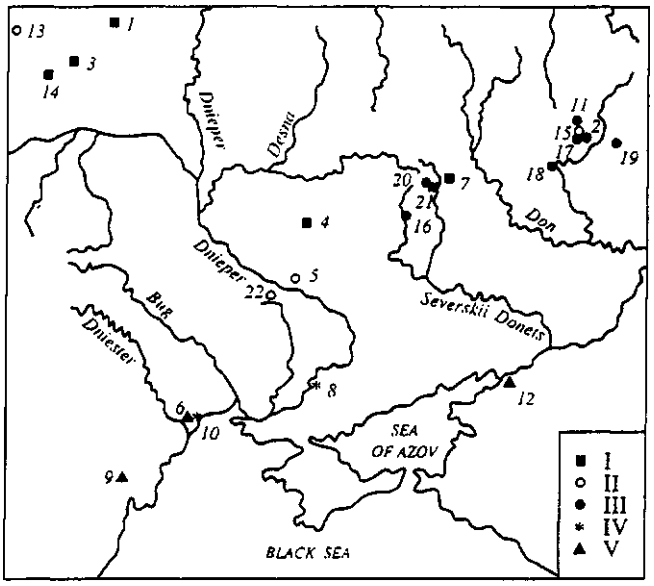

Fig. 1. Geographical position of green toad localities on the Russian Platform: (I) the Holocene and Upper Pleistocene, (П) Middle Pleistocene, (III) Lower Pleistocene, (IV) Eopleistocene, (V) Pliocene; (7) Brod, (2) Vol'naya Vershina-II, *(3)* Voroncha, *(4)* Gadyach, (5) Gun'ki-II and -III, *(6)* Zapadnaya Peshchera, (7) Zmeevka-II, *(8)* Karai-Dubina, *(9)* Kotlovina, (70) Kryzhanovka, (77) Kuznetsovka, (72) Liventsovka, *{13)* Nyaravai, *(14)* Peski-I, (75) Posevkino, *(16)* Repnoe, (77) Soglasie-Korostelevo. *(18)* Troitskoe, (79) Trostnyanka, *(20)* Kholki. (27) Chernyanka, (22) Chigirin.

DESCRIPTIONS AND COMPARISON

Description of Bone Remains

My observations have shown that a species diagnosis of green toads may be worked out on the basis of the sphenethmoid, maxillary and frontoparietal bones, parasphenoids, scapular, humeral, iliac, and femoral bones; and sometimes the presacral vertebrae and clavicles. Finds of these bones in the localities, made it possible to substantiate the existence of particular species in the Russian Platform in the past. The majority of these bones have common features distinguishing them from those of grey toads, hence avoiding need for comparison with them in specific identifications. In bone descriptions, I employ previously used terminology (Ratnikov, 1994a).

Sphenethmoideum usually has broad posterior foramens of the olfactory canals and high folds in their cavities. Grey toads usually have narrow foramens and only slightly pronounced folds.

Maxillare: the anterior edge of *pars facialis* reaches up to the anterior edge of *pars dentalis,* whereas in grey toads the anterior edge of *pars facialis* extends beyond the level of *pars dentalis.*

Frontoparietal of green toads has lateral edge turned downwards smoothly; the lateral edge of the flattened parietal part may have a well-pronounced crest; lateral process of the bone forms a peculiar "peak" hanging over the anterior edge of the prootic bone. The frontoparietal in grey toads is flattened all along the dorsal surface; the lateral edge of the bone is turned downwards abruptly; the lateral process forms no "peak" over the anterior edge of the prootic bone.

Parasphenoideum of green toads has flattened ventral surface within the area of branching of lateral processes. In grey toads a marked bending is observed in this position.

In green toads, the articular surfaces of thoracic vertebral centra are very broad and greatly flattened dorsoventrally; as a rule, the posterior edge of the ventral surface of the neural arch in the lumbar vertebrae juts out over the posterior edge of the dorsal surface; diapophyses are slightly or not at all widened at the base. In grey toads, the thoracic vertebral centra are oval in cross section; in the lumbar vertebrae, cotyluses are usually crescent-shaped; as a rule, the posterior edge of the dorsal surface of neural arch hangs over the posterior edge of the ventral surface; diapophyses are widened at the base and flattened.

Humerus has slightly convex to flat dorsal surface in its distal part and relatively less widened head than in grey toads.

Ilium has comparatively thin *ala ossis ilii* and "calamita's" crest of different appearance on the ventro-lateral side (this structure was called the "calamita blade" by Sanchiz and "calamita ridge" by Holman, 1989). In *B. viridis* and *B. raddei,* the posterior end of the ventral edge of this crest reaches the anterior edge of the *acetabulum* and, as a rule, forms a well-pronounced preacetabular cavity. In *B. calamita* the posterior edge of this crest rises higher, and no preacetabular cavity forms. In grey toads, *ala ossis ilii* is relatively thicker, has no crest on the ventral side; preacetabular cavity is absent.

In green toads, femoral crest is somewhat longer than in grey toads.

Bufo viridis Laurenti, 1768

Comparative description. *Sphenethmoideum* (Fig. 2a) is moderately long (the length approximates with the width); the crests bordering ventral surface are smooth; roof is short; posterior part of the ventral area is broad; lateral processes are of moderate length. In *B. raddei* and *B. calamita,* the sphenethmoids have well-pronounced sharp crests bordering the ventral surface; narrower posterior part of the ventral area; and longer lateral processes.

Maxillare (Fig. 2b). Anterosuperior edge of *pars facialis* reaches the anterior edge level of *pars dentalis;* the posterior edge of *pars palatine* has a distinct process. In contrast, in *B. raddei* and *B. calamita,* the anterosuperior edge of *pars facialis* is shorter; and the process at the posterior edge of *pars palatina* is slightly marked.

Frontoparietale (Fig. 2c) is distinguished from that of *B. raddei* and *B. calamita* by the absence of a sharp narrowing in the anterior part; and by a slightly marked crest represented in some cases on the lateral edge of the flattened parietal part.

Parasphenoideum (Fig. 2d). The body is substantially wider than the lateral processes, its flattened part is broad; whereas in *B. raddei* and *B. calamita* the bone body and its flattened part markedly narrower.

Clavicula (Fig. 2f). Identification of species using this bone is not always reliable. In particular, clavicles of green and grey toads are very similar in shape; but in the former they are distinguished by the less widened lateral edge and by the shape of the lateral edge bend. The bone is distinguished from that in *B. raddei* by lesser width; and from *B. calamita,* by slightly curved anterior edge.

Scapula (Fig. 2g) is rather short, massive, has a wide neck and acromial part; anterior edge of the latter stretches to form the *tenuitas acromialis.* In massiveness and neck width of scapula, *B. viridis* differs from nearly all toads of Russia, except for *B. verrucosissimus* that is distinguished by the outline of the scapula body.

Humerus (Figs. 2h-2j) is a relatively long and thin bone with simple structure of the proximal part *{crista ventralis secundaria* is absent), as distinct from *B. raddei* and *B. calamita. Crista medialis* is of moderate width, having a straightened edge, slightly turned back dorsally.

Ilium (Figs. 2k-2n). Holman (1989) considers the presence of the acetabular cavity and bifurcated dorsal

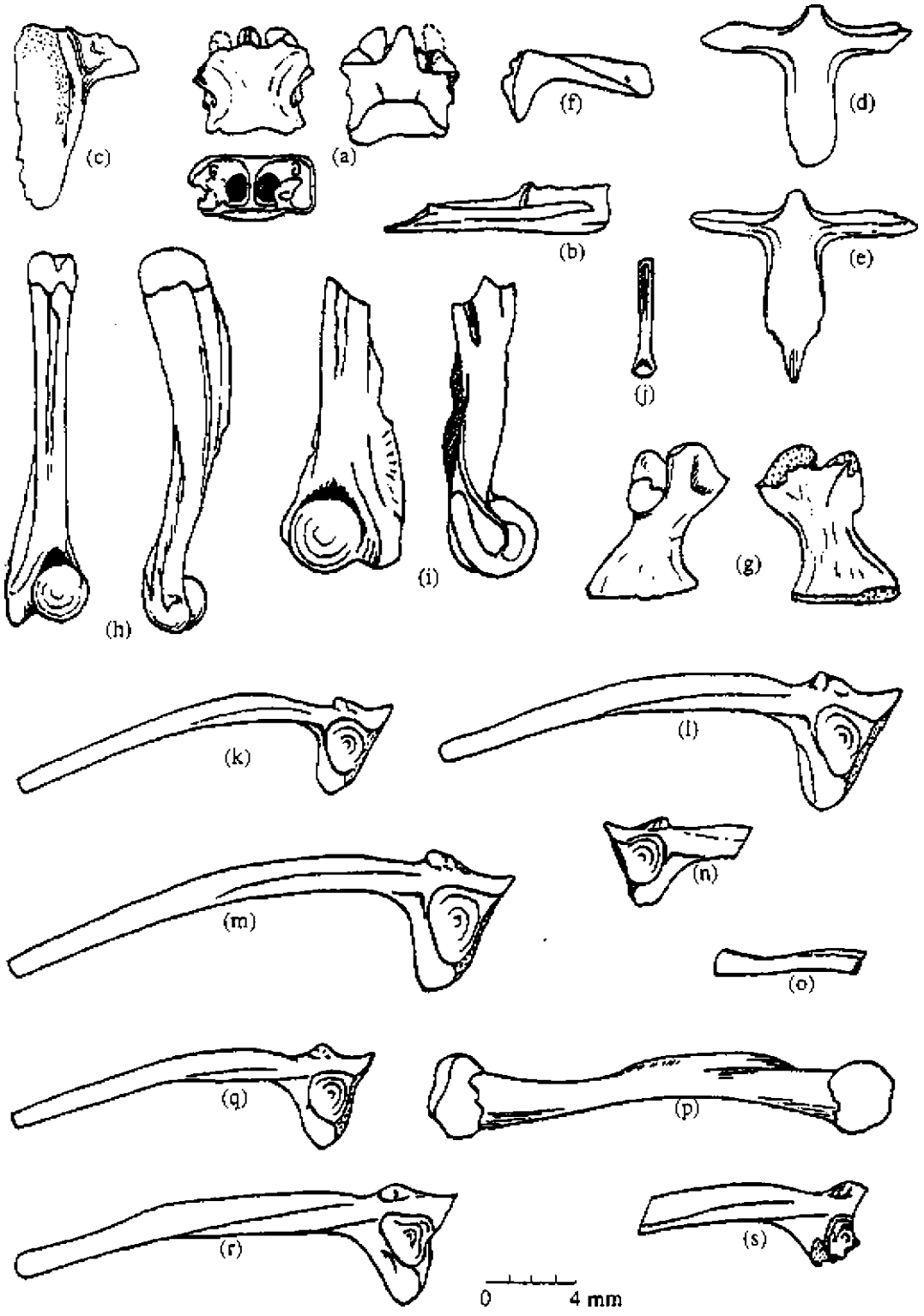

Fig. 2. Bones of green and running toads: (a-p) *Bufo viridis:* (a) *sphenethmoideum* (VGU no. 559-1/2835), ventral, dorsal, and anterior views, Zmeevka-II; (b) *maxillare* (VGU no. 559-1/2576), medial view, Zmeevka-II; (c) *accrettdfrondorsalarietale andprooticum* (VGU no. 559-1/2586), dorsal view, Zmeevka-II; (d) *parasphenoideum* (VGU no. 559-1/2598), ventral view, Zmeevka-II; **(e)** *parasphenoideum.* ventral view, extant; (f) *clavicula* (VGU no. 559-1/1048), dorsal view, Zmeevka-II; *(°)scapula* (VGU no. 557-1/67), ventral and dorsal views, Chernyanka; (h) *humerus,* ventral and lateral views, extant; (i) *humerus* (VGU no. 557-1/1), ventral and lateral views, Chernyanka; (j) *humerus* (VGU no. 517/11), ventral view, Gadyach; (k-m) *ilium,* lateral view, extant; (n) *ilium* (VGU no. 557-1/44), lateral view. Chernyanka; *(o)femur,* dorsal view, extant; (q-s) *Bufo calamita:* (q, **r)** *ilium,* lateral view, extant; (s) *ilium* (VGU no. 544/7). lateral view, Peski-I.

convexity as characteristic of *B. viridis,* distinguishing it from *B. bufo* and *B. calamita.* However, *B. raddei* possesses this trait. In my comparative material, the *tuber superior* in 5. *viridis* more often possesses one small simple pinea rarely having two apexes; sometimes there are more pineas. In all my comparative samples, *B. raddei* possesses one large pinea on the *tuber superior,* most frequently it is bifurcated or has a cavity at the top. Hodrova (Hodrova, 1986) noticed this characteristic when describing remains of *B. raddei* from the Pliocene Bural-Obo Locality of Mongolia. The *tuber superior* of Mongolian toads from the Eopleistocene localities of Transbaikalia has the same shape (not published). In my opinion, the iliac bone of *B. viridis* is distinguished by the noticeable asymmetry of the *tuber superior,* the anterior edge of which ends far more abruptly than the posterior.

Femur (Figs. 2o, 2p) has the shortest *crista femoralis* and the smallest diameter of cross section in comparison with the same features in *B. raddei* and *B. calamita.*

Material. Brod: three humeral bones; Voroncha: one humeral bone; Gadyach: one humeral and one femoral bones; Zmeevka-II: 117 bones identified to species accuracy; Chernyanka: 41 bones identified to species accuracy.

Bufo calamita Laurenti, 1768

Description and comparison. *Ilium* (Figs. 2q-2s). Originally I assigned these two finds to *Bufo cf. viridis* (Kalinovskii and Ratnikov, 1990). However, relatively thin *ala ossis ilii* and the absence of a preacetabular cavity make them similar to *B. calamita. Tuber superior* is high, complicated with small slightly noticeable pineas.

Material. Peski-I: one iliac bone; Nyaravai: one iliac bone.

Bufo raddei Strauch, 1876

Description and comparison. *Vertebrae* (Fig. 3a) are insufficiently reliable for species identification: vertebrae of different species are usually similar in their shape. However, some vertebrae of *B. raddei* in my comparative material possess singular sublongitudinal ridges on the neural arch. Vertebrae of *B. viridis* and *B. calamita* lack such structures; I therefore assigned fossil vertebrae with analogous ridges to *B. raddei.*

Clavicula (Fig. 3b) is a massive bone with characteristic widening of the medial part that distinguishes *B. raddei* from the other toad species of Russia.

Scapula (Figs. 3c, 3d) is markedly distinguished from that of other toads by its elongated shape, narrower neck and acromial part. Recent material studied demonstrate variations in the scapula shape of *B. raddei:* from narrow that are characteristic of Mongolian samples to broader similar to the scapulae of *B. calamita* in shape. Fossil scapulae assigned to *B. raddei* are similar to those of the Mongolian samples. A scapula with a wider neck was found in the Soglasie-Korostelevo Locality and may be assigned either to *B. raddei* or to *B. calamita.*

Humerus (Figs. 3e-3g) is massive; medial crest is wide, with roundish edge, turned back dorsally; *crista ventralis secundaria* is well-pronounced having a deep ledge-shaped depression at its proximal edge. Humeral bones of *B. raddei* are very easy to be distinguished from that of *B. viridis* by their massiveness and structure of the proximal end; they differ from the humeral bones of *B. calamita* in the shape of the medial crest and somewhat greater mass.

Ilium (Figs. 3h-3q). A distinctive peculiarity is the presence of a high *tuber superior* rising symmetrically or nearly symmetrically, having a pinea in the central part divided into two tops in most cases. Fossil material that I assigned to *B. raddei* shows diversity in the shape of the *tuber superior:* in some samples its height is lower than usual; in some, its posterior side slopes more gently than the anterior (but more abruptly than it is typical of *B. viridis);* and some samples possess a pinea without subdivision. In my opinion, the samples are closer in their morphology to *B. raddei* than to *B. viridis;* though, the existence of an intermediate (perhaps ancestral) form is not inconceivable.

Material. Peshchera Zapadnaya (Odessa Catacombs): four iliac bones; Kotlovina: two iliac bones; Liventsovka-П: one humeral bone; Liventsovka-V: one iliac bone; Karai-Dubina: one iliac bone; Kryzhanovka: two iliac bones; Vol'naya Vershina-II: one scapula, one humeral, one iliac bone; Kuznetsovka: two iliac bones; Trostnyanka: one iliac bone; Soglasie-Korostelevo: one iliac bone; Troitskoe: two vertebrae, three iliac bones; Repnoe: one clavicle, one scapula; Kholki: one scapula; Gun'ki-II: two scapulae, one humeral bone, two iliac, and two femoral bones; Gun'ki-Ш: one iliac bone; Posevkino: one vertebra, one scapula, six iliac bones, and one femoral bone; Chigirin: one clavicle.

DISCUSSION

On the basis of the material described above, one may conclude that *B. calamita* inhabited the area of its present day territories in Eastern Europe in the Middle Pleistocene (Fig. 1). All reliable finds of *B. viridis* are restricted to the Late Pleistocene-Holocene; whereas in the Late Pliocene-Middle Pleistocene *B. raddei,* or at least a species closely resembling it, is found persistently in the Russian Platform. In the Late Pliocene the Mongolian toad seems to have occupied a vast area including, besides its recent natural habitat, the southern Russian Platform, where it had persisted up to the Middle Pleistocene. The Green toad, inhabiting Eastern Europe appeared there only recently in the Late Pleistocene, when the area of the Mongolian toad had been reduced substantially. Unfortunately, the known material

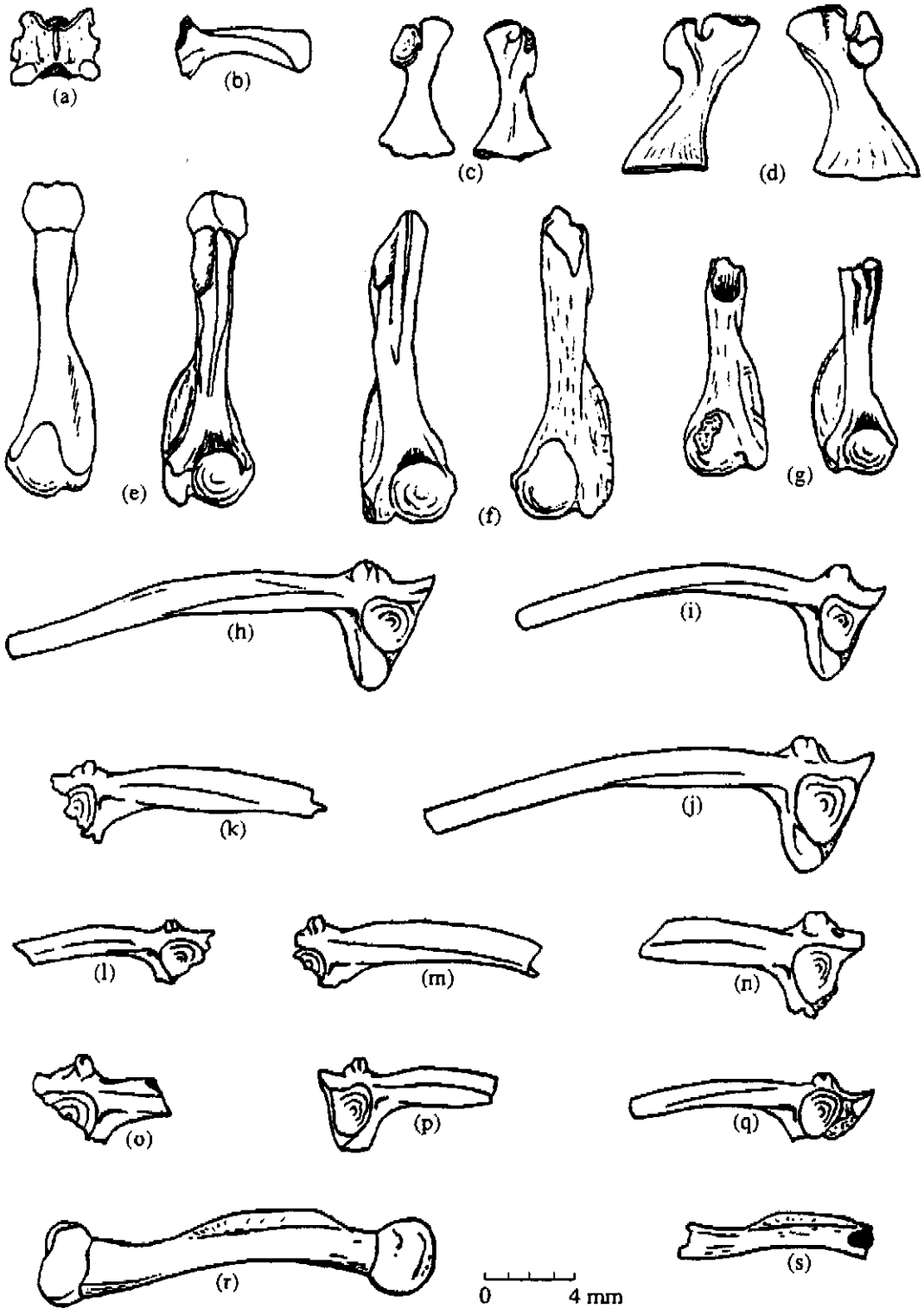

Fig. 3. Bones of Mongolian toad *Bufo raddei:* (a) *vertebra* (VGU no. 515/43), dorsal view, Posevkino; (b) *clavicula* (VGU no. 513/12), dorsal view. Chigirin; (c) *scapula* (VGU no. 516b/21), ventral and dorsal views, Gun'ki-II; (d) *scapula,* dorsal and ventral views, extant; (e) *humerus,* dorsal and ventral views, extant; (0 *humerus* (VGU no. 501 -2/1), ventral and dorsal views, Vol'naya Vershina-II; (g) *humerus* (VGU no. 516b/9), dorsal and ventral views, Gun'ki-II; *(h-])ilium,* lateral view, extant; (k) *ilium,* (VGU no. 515/5), lateral view. Posevkino: (1) *ilium* (VGU no. 540/1), lateral view, Zapadnaya Peshchera; (m) *ilium* (VGU no. 510/2), lateral view, Karai-Dubina; (n) *ilium* (VGU no. 511/1), lateral view, Kryzhanovka; (o)i7uim(VGU no. 508/1), lateral view, Soglasie-Korostelevo; (p) *ilium.* (VGU no. 515/4), lateral view, Posevkino; (q) *ilium* (VGU no. 516b/4), lateral view. Gun'ki-II; *(x) femur,* dorsal view, extant; (s) *femur* (VGU no. 516b/20), dorsal view, Gun'ki-II.

is not sufficient enough to reveal the boundaries of the natural habitat and its temporal variations.

However, it is noteworthy that toad remains that I have assigned to *B.* cf. *viridis* and *B.* aff. *viridis* were found in two or three yet unstudied localities, older than the Late Pleistocene. This indicates the possibility that *B. raddei* coexisted with the green toad, or a species closely related to it, in the Russian Platform.

It seems cumous that the remains of the Mongolian toad, a form persisting in Eastern Europe for such a long time, are completely absent in Western and Central Europe; whereas the green toad, known there from the Middle Miocene, appeared in the Russian Platform only in the Late Pleistocene. Hence, I have analyzed data in the available publications of western authors and found out the following:

(1) In the lists of remains from localities older than the Late Pleistocene, green toads are usually identified with uncertainty, namely as *B.* cf. *viridis* and *B.* aff. *viridis.*

(2) As a rule, fossil remains were compared only with the species recently inhabiting the territories studied.

Such a situation may be explained by two reasons: firstly, great difficulties in the establishing of osteological collections; secondly, a widely held view on amphibians is that they are unable to change their habitat range substantially. In this connection, the samples that are distinguished from the green and running toads that inhabited Western Europe in recent times, are assigned to a species similar or related to the European species. For example, Sanchiz (1977) described green and running toads from the Miocene and Pliocene of Spain in a paper that is frequently referred to by other specialists. At the end of the paper, a long list of species from the author's comparative collection is represented; but it lacks the Mongolian toad. Unfortunately, photographs of the bones are not very good; nevertheless, some iliac bones of *B.* cf. *calamita* and *B.* cf. (aff.) *viridis* seem to be closer to *B. raddei* in their morphology. In my opinion, insufficiently conclusive fossil remains of green toads from Western and Central Europe should be revised with comparisons made in particular with *B. raddei.*

These conclusions are admittedly based on an insufficiently representative comparative collection. Among other things, I lack good samples of the recently described *B. danatensis* that inhabits the Altai; a form occurring nearer to Europe than *B raddei.* However, a specimen of this species that I recently obtained shows great similarity with *B. viridis* in the structure of the iliac bones; and thus, at least fossil iliac bones from the East European localities that are older than the Late Pleistocene are not comparable with this species.

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